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ABSTRACT

This study examined the nature of sex-related differences in spatial ability. Results indicated that sex-related cognitive differences are concentrated among subjects having poor spatial ability. Suggestions for remedial education of females and males are given. (MK)

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The Differentiation of Spatial and Analytic Ability

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Analysis of intelligance tests has shown that intelligence, from a psychometric perspective, is not a unitary factor but is composed of several factors. One of those is Spatial Ability, which by definition is that ability which is responsible for the common correlation which exists among a cluster of tests which includes the Identical Blocks test, the Flags test, and other tests which require visualization skill.

Two characteristics of Spatial Ability are: 1) it is unique among Primary Mental Abilities (Thurstone) in that consistent differences as a function of sex are found (males are superior in this ability); 2) it is highly correlated with achievement in science. Because of 1 and 2, it has been proposed that sex related differences in Spatial Ability may be causally linked with sex related differences in achievement in science.

This study examined a test of visual decontextualization ability, which is correlated with Spatial Ability, from the perspective of Genetic Epistemology. The purpose of taking the perspective of Genetic Epistemology was to examine visual decontextualization ability and determine whether it is primarily a correlate of perceptual ability, imagery ability, or logical reasoning ability. Following determination of the primary correlates, discriminant analysis was used to determine whether group differences exist with respect to the Genetic Epistemological measures. Four groups were defined on the basis of sex and high/low visual decontextualization ability.

It was anticipated that those analyses would shed new light on the nature of visual decontextualization and Spatial abilities, and also identify the nature of sex related differences in those abilities.

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Subjects:

The sample consisted of 28 girls and 28 boys between the ages 14 years 6 months and 16 years 8 months (mean age 15 years 5 months). The subjects were enrolled in an academic mainstream Biology course in a Syracuse New York Public School. Subjects were in the 10th grade. The sample was selected randomly from a pool formed by the total population of students enrolled in the course in that school (198 students in total). The school population was mixed with respect to Socioeconomic status, ethnic groups, and levels of parental education.

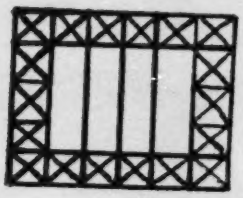
Apparatus and Materials:

Spatial Ability was assessed with the Group Embedded Figures Test, and constituted the dependent variable of the study. Piagetian tasks were selected from Mental Imagery in the Child (Piaget and Inhelder, 1971) in accordance with the following criteria: 1) that each task be very simple, so that distinction between perceptual and cognitive operational factors could be made; 2) that the composit set of tasks assess the full range of factors which might contribute towards performance on the Group Embedded Figures test. The selected tasks were: 1) Perception, 2) Simple Imagery, 3) Pseudo-Conservation, 4) Complex Imagery, 5) Problem Solving (from Psychology and Epistemology of Functions, Piaget et.al., 1977). Examples of each task, and of the Group Embedded Figures test, are given in Figure #1, #2, and #3.

Sample Group Embedded Figures Test items (total test = 18 items).

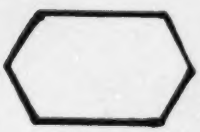
FIND SIMPLE FORM "A"

FIND SIMPLE FORM "B"



SIMPLE FORMS

A



B

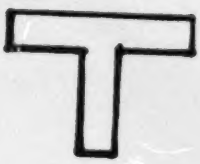
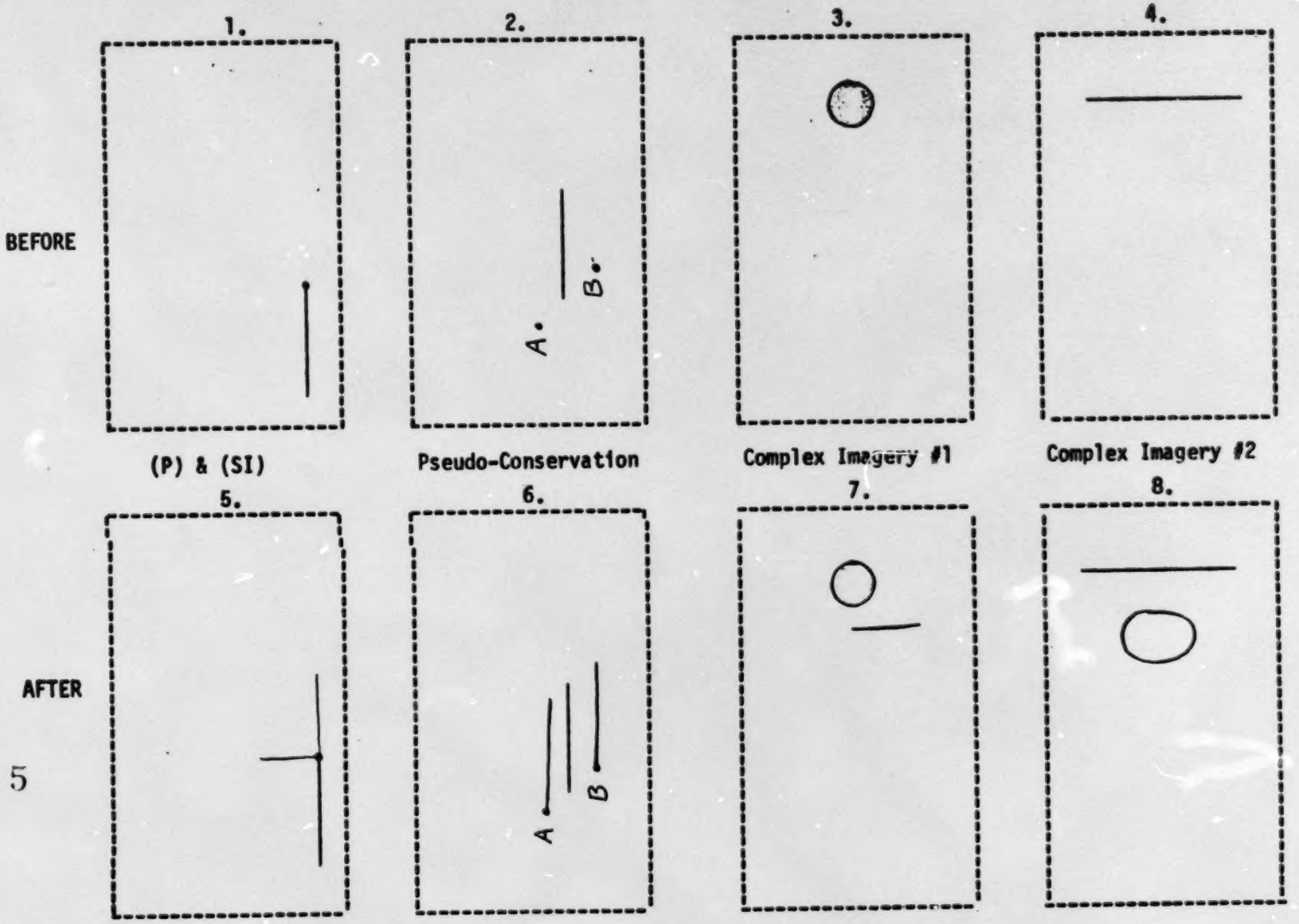


FIGURE 2

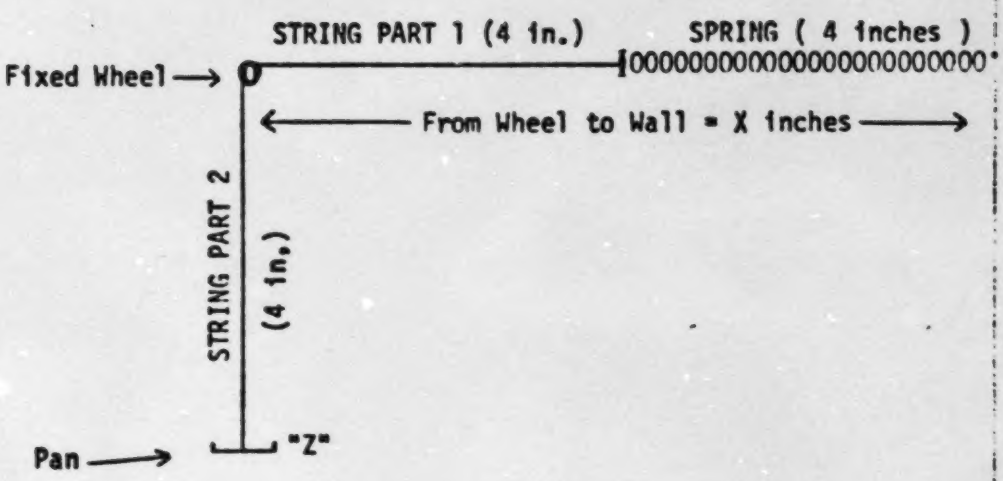
FIGURES OF PIAGETIAN TASKS



Wall →

FIGURE 3

SCHEMATIC OF PROBLEM



One end of a string is tied to a pan. The other end is fastened to a spring. The string is hung over a fixed wheel. The spring is screwed into the wall. The spring is 4 inches long when it is not stretched (as in the picture). The part of the string from the spring to the wheel is 4 inches long, and the part from the wheel to the pan is 4 inches ling. Answer the following questions:

1) How long is the whole string? _____.

2) How far is it from the wheel to the wall? _____.

Now you add five pounds of lead to the pan (Z). The SPRING stretches, so that it is now 5 inches long. Answer the following questions.

3) How long is the string? _____.

4) How far is it from the wheel to the Pan (Z)? _____.

5) How far is it from the Wheel to the Wall? _____.

6) How far is it from the Wheel to the SPRING? _____.

7) You add five more pounds of lead, and the spring stretches to 5½ inches; if you add five pounds of lead again, how far will the spring stretch? _____.

Data Analysis:

The question: What is the nature of sex related differences in Spatial Ability? was decomposed into two research questions, each of which was quantitatively evaluated as follows:

Question #1: Which of the following variables accounts for the greatest amount of variance in Group Embedded Figures test scores: Perception, Simple Imagery, Pseudo-Conservation, Complex Imagery, or Problem Solving?

This question was quantitatively analyzed by hierarchial multiple regression, where the independent variables were regressed on Group Embedded Figures test score in the above order. In addition, the Part Correlation and Partial Correlation of each independent variable was determined so that the unique contribution of each could be obtained. Results are tabulated in Table 1.

Question #2: Of the above independent variables and the additional variable Written Explanation of Complex Imagery, which best discriminate between the groups Low Spatial Ability Males, High Spatial Ability Males, Low Spatial Ability Females, High Spatial Ability Females?

This question was quantitatively analyzed by stepwise discriminant analysis (Rao's"V" method). Results are tabulated in Table 2.

Results:

Question #1: The variables Complex Imagery and Problem Solving were significantly (alpha $\leq$ .05) correlated with the Group Embedded Figures test. When each independent variable was partialed out (i.e. was forced into the regression equation last, and the resultant R^2 used to calculate the Partial Correlation), it was shown that Problem Solving was

the unique significant correlate of Group Embedded Figures test (GEFT) score. Most of the variance common to Complex Imagery and GEFT was due to the contribution of cognitive reasoning (Problem Solving) to both; thus, when Complex Imagery and GEFT were controlled for Problem Solving (Partial Correlation), the correlation between them was no longer significant. This result confirms two points: 1) that Complex Imagery is a measure of the interaction of imagery and logical thought, as Piaget claims; 2) that the Group Embedded Figures Test is primarily a measure of cognitive thought, not perception or imagery.

Question #2: The variables Problem Solving, Pseudo-Conservation, and Transformation of a Straight Line into a Circle (Complex Imagery 2), significantly discriminated between groups. No significant difference existed between high GEFT score males and females. A significant difference between high GEFT score (males & females) and low GEFT score (male & female) subjects was due primarily to Problem Solving. This indicates that low GEFT score subjects, regardless of sex, are poorer in logical reasoning than are high GEFT score subjects. A significant sex difference existed between low GEFT score males and females. Females were significantly poorer in cognitive ability. Males were significantly poorer in Pseudo-Conservation.

Discussion:

The results of this study indicate that sex related cognitive differences are concentrated among subjects having poor spatial ability. High GEFT score subjects exhibited high cognitive operational ability, regardless of sex. Low GEFT score subjects were low in cognitive operational ability, but a

significant sex difference was found. Females were significantly poorer in cognitive operational ability than were males (for low GEFT score subjects). Males were significantly poorer in mental imagery than were females (for low GEFT score subjects).

The results support the hypothesis that the GEFT measures different aspects of performance for males and females. Females have difficulty in visual disembedding due to a deficit in operational reasoning. The test of operational thinking used in this study, Problem Solving (fig. 3), called for very specific logical operations (Piaget, 1977, p. 49 - 64). The test of mental imagery used in this study was designed specifically as a discriminator of operational and imagery factors. The other tests used in this study (Perception, Simple Imagery) were specifically selected to assess those simple skills which are often named as the source of sex differences. Contrary to the often stated premise that the sex difference in Spatial Ability is due to a deficit in visualization skills for females, this study concludes that males (low GEFT group) are the one's having a deficit in visualization skills, and females have a deficit in operational ability.

These results indicate that remedial education for females should focus on developing cognitive ability. Hands on experience in classifying, seriating, identifying similarities of grouped objects, identifying differences of grouped objects, hypothesizing, predicting, risk taking, and naming the principles behind transformations are appropiate means of developing operational ability. Remedial education for low GEFT score males should also emphasize cognitive operational processes, but should also focus on improving imagery skills such as directing attention to appropiate perceptual clues (at which females excell).

INDEX OF ABBREVIATIONS

P = PERCEPTION (simple reproduction of a straight line)

SI = SIMPLE IMAGERY (reproduction of rotated straight line)

PC1 = Pseudo-Conservation (length of line from point "A")

PC2 = Pseudo-Conservation (length of line from point "B")

CL = Complex Imagery (transformation of a circle into a straight line)

LC = Complex Imagery (transformation of a straight line into a circle)

PS = Problem Solving (problem set score)

SA = Spatial Ability (GEFT score)

FDM = Field dependent male (low GEFT score males; 11 points and less)

FIM = Field independent male (high GEFT score males; 12 points and more)

FDF = Field dependent female (low GEFT score females; 11 points and less)

FIF = Field independent females (high GEFT score females; 12 points and more).

TABLE 1
MULTIPLE REGRESSION SUMMARY TABLE

	R^2	F	$(\text{PART Cor.})^2$	$(\text{PARTIAL C})^2$	OVERALL
P	.003	.907	.011	.018	F = 5.27*
SI	.031	1.984	.025	.040	DF = 6, 49
PC1	.032	.605	.008	.013	SEE = .82
PC2	.039	1.192	.015	.024	
CL	.168	2.562*	.032	.050	
PS	.392	18.056*	.224	.269	

* significant at $\alpha \leq .05$ level of statistical significance

TABLE 2

DISCRIMINANT ANALYSIS SUMMARY TABLE

	FUNC. 0	FUNC. 1	FUNC. 2	FUNC. 3	Rao's"V"/sig.
PS		.851	-.319	-.392	30.5/.000
LC		-.253	-.852	.016	38.1/.000
PCl		-.014	.656	.006	45.4/.000
WE		.274	.119	.982	49.4/.000
Eigen/ value		.65	.18	.12	
Canon'cl/ Corr'ltn.		.63	.40	.32	
% s^2		68%	19%	12%	
Wilks' Lambda (after)	.46	.76	.90		
Chi Sqared (Wilks')	39.8	14.3	5.6		
D.F.	12	6	2		
sig'n.	.000	.027	.060		
GROUPS					
FDM		-.433	-.657	.135	
FIM		.718	-.031	-.481	
FDF		-1.055	.434	-.076	
FIF		.771	.254	.421	

F statistics for significances between pairs of groups

	FDM	FIM	FDF	
FIM	3.46/.01			
FDF	2.68/.04	5.81/.00		D.F. = 4, 49
FIF	3.89/.01	1.48/.22	5.96/.00	12

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